# Mineral Compositions of Tap, Filtered and Bottled Waters in Bahrain

**Afnan M. Freije, Sameera M. Sayeed, Humood A. Naser**

***ABSTRACT--- The concentrations of the minerals magnesium (Mg2+), calcium (Ca2+), sodium (Na+) and potassium(K+) were determined in tap, filtered and bottled waters in Bahrain using atomic absorption spectroscopy. Tap and filtered water samples were obtained from the households of ten different cities in Bahrain, while twenty different commercial brands of bottled water samples were purchased from supermarkets and hypermarket in Bahrain. Significant differences (p<0.05) were recorded between the pH values of tap, filtered and bottled water samples. The pH valuesfor allwater samples ranged between 6.61 and 8.39 in whichthe lowest concentration was recorded in filtered water samples (6.96 ± 0.24), whereas bottled water samples had the highest values (7.63 ± 0.27). Filtered water samples also had the lowest magnesium concentration (0.67 ± 0.52 mg/L) in comparison to bottled water samples (13.79 ± 9.80 mg/L) and tap water samples (1.825 ± 1.08 mg/L). Calcium concentration was significantly higher (p<0.05) in tap water samples (64.95 ± 5.35 mg/L), whereas the lowest concentration was recorded in bottled water samples (17.87 ± 18.68 mg/L). Tap water samples also had significantly higher (p<0.05) sodium concentration (15.67 ± 3.93 mg/L) compared to filtered water samples (9.02 ± 2.41 mg/L) and bottled water samples (8.53 ± 9.59 mg/L). Potassium was found to have the lowest concentration in filtered water samples (1.60 ± 1.67 mg/L), whereas no significant differences was recordedbetween tap water samples (3.76 ± 1.39 mg/L) and bottled water samples (3.63 ± 4.03 mg/L). The findings of the present study have indicated that in terms of all components investigated, the quality of tap water in Bahrain is better than filtered water and with minor improvement in the concentration of magnesium can be considered as good as bottled water.***

***Index Terms—Filtered, Bottled, Minerals, Tap, Drinking Water, Arabian Gulf.***

## I. INTRODUCTION

The United Nations Sustainable Development Goals (SDGs) agenda recognizes the importance of water for sustainable development. Globally, there are concerns overwater management, water resources, water access, and water quality [1]. These concerns are reflected on SDG No. 6. Nonetheless, water is connected to the other SDGs, especially those addressing food, energy, and environment forming a nexus of Water-Food-Energy that is central to sustainable development [2].

Water resources and management are major challenges facing the Arabian Gulf countries [3]. The Arabian Gulf is characterized by high aridity and low precipitation. The average annual rainfall in the Arabian Gulf ranges between 70 and 140 mm [4]. On the other hand, the Arabian Gulf countries are witnessing rapid economic, industrial and social developments associated with population growth [5]. Therefore, the demand for fresh water is rising rapidly in the Arabian Gulf region.

Seawater desalination is emerging as the prime option to secure the growing needs for potable water in the Arabian Gulf. It is estimated that the amount of desalinated water in the Arabian Gulf region accounts for more than 60% of the world's total production [6]. Several desalination technologies are being used in the Arabian Gulf, including Multi-Stage Flash (MSF), and seawater or brackish Reverse Osmosis (RO) [7].

In Bahrain, provision of pure drinking water has always been a major challenge due to limited groundwater, scarce rainfall and arid climate, which is being intensified by increasing environmental pollution and climate. Additionally, increasing population, accelerating industrial development and improving lifestyles have led to increased demand of better-quality drinking water in Bahrain [8].

There are three main sources of drinking water in Bahrain, namely tap water, filtered water and bottled water [9]. Tap water is mainly obtained from both desalinated water and ground water. Typically these two waters are blended, subjected to purification process and then supplied through pipelines for drinking and other purposes. Presently, there are five main desalination plants that serve to treat and cleanse water using both MSF and RO technologies [8]. Filtered water is mostly tap water that subjected to filtration through carbon filters to remove chlorine and thereby improving the taste and further purifying the water. This process is conducted by privately owned companies or through filtration equipment in households [10].

Bottled water is a drinking water acquired from a protected source which has been treated to achieve purity and to which minerals may be added. This water is then packaged in plastic or glass bottles and sold by different brands around the world [11]. In recent years, there has been a rapid increase in the consumption of bottled water by the public in Bahrain. This could be attributed to negativeperceptions of the public towards the quality of tap water. Additionally, people may prefer the taste of specific brands of bottled water over tap water [12]. However, consumption of bottled water is associated with several health, environmental and economic implications. This source of water is generally costly, and can generate plastic waste [13, 14].

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Minerals such as sodium, potassium, calcium, and magnesium are considered to be vital for good nutrition. They are present in water in the form of ions due to dissociation and are very important for the proper functioning of the body systems and the general aspects of health [15]. Characterizing the levels of minerals in various sources of drinking water is also important for effective governance and management. Therefore, the main aim of the present study is determine the concentrations of four minerals (calcium, magnesium, sodium and potassium) as well as the level of pH in tap, filtered and bottled waters consumed in Bahrain.

## II. MATERIALS AND METHODS

### *A. Sample Collection*

A total of 50 tap water samples and 50 filtered water samples were collected from 10 main cities of the four governorates in Bahrain (Table 1). Five tap water samples and five filtered water samples were randomly collected from five different households in each of the main cities of the four governorates in Bahrain.

**Table 1: Tap water and filtered water collection based on main cities of the four governorates in Bahrain.**

| Governorates | Main cities |
|---|---|
| Capital Governorate | Manama |
| | Sitra |
| | Budaiya |
| Northern Governorate | A'ali |
| | Hamad Town |
| | Riffa |
| Southern Governorate | Isa Town |
| | Sakhir |
| Muharraq Governorate | Al-Muharraq |
| | Al-Hidd |

Twenty bottled water brands were randomly collected from the main supermarkets and hypermarkets in Bahrain. Five samples from eachbottled water brand were purchased. The pH values were recorded for all collected water samples.

### *B. Mineral Analyses*

The minerals $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$ in water samples were determined using atomic absorption spectroscopy (PerkinElmer TM instruments). Twelve standard solutions containing 0.25, 0.5, 0.75, 1.0, 1.25, 2.5, 5, 10, 20, 40, 80 and 100 mg/L of the ions $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$ were prepared from $CaCO_3$ stock solutions (1000 mg/L). The standard solution sets were prepared based on the concentrations of the minerals of the different bottled water brands used in the present study as well asthe mineral contents of tap and filtered waters obtained from the study conducted by Musaiger and Khunji [9]. Water samples were filtered using 0.45µm pore size filters prior to analysis on atomic absorption spectroscopy.

### *C. Statistical Analysis*

The statistical analysis was performed using the statistical package from Minitab (Minitab Inc., PA, USA, 2013). Results are presented as mean values and standard deviation (mean±SD).The mean values of each measured parameter were statistically analyzed using One-way analysis of variance (ANOVA) followed by Tukey's Honestly Significant Difference (HSD Post Hoc) test. Differences with p value <0.05 were considered statistically significant.

## III. RESULTS

The pH values of tap water ranged from 6.61 to 7.77. Tap water samples from Sitra had the highest concentration of magnesium (3.37 ± 0.12 mg/L), whereas tap water samples from Sakhir had the highest concentration of calcium (70.27 ± 2.13 mg/L) and potassium (5.06 ± 0.35 mg/L). Tap water samples from Hamad Town had the highest sodium concentration (24.17 ± 1.50 mg/L) (Table 2).

**Table 2: pH and mineral compositions of tap water in Bahrain (Mean ± SD, n = 5).**

| Governorates | Cities | pH | Mangnesium (mg/L) | Calcium (mg/L) | Sodium (mg/L) | Potassium (mg/L) |
|---|---|---|---|---|---|---|
| Capital | Manama | 7.59 ± 0.03 | 0.93 ± 0.08 | 55.09 ± 2.86 | 17.43 ± 0.69 | 3.89 ± 0.06 |
| | Sitra | 6.64 ± 0.15 | 3.37 ± 0.12 | 56.34 ± 2.10 | 12.33 ± 0.32 | 3.95 ± 0.49 |
| Northern | Aali | 7.54 ± 0.11 | 3.04 ± 0.50 | 65.97 ± 2.08 | 13.76 ± 0.13 | 4.68 ± 0.24 |
| | Budaiya | 7.77 ± 0.08 | 1.58 ± 0.23 | 68.02 ± 1.90 | 10.13 ± 0.55 | 2.35 ± 0.14 |
| | Hamad Town | 7.51 ± 0.04 | 1.32 ± 0.37 | 67.46 ± 2.04 | 24.17 ± 1.50 | 4.60 ± 0.47 |
| Southern | Isa Town | 7.51 ± 0.11 | 2.35 ± 0.21 | 68.06 ± 2.67 | 14.45 ± 0.17 | 4.48 ± 0.44 |
| | Riffa | 6.61 ± 0.06 | 3.09 ± 1.31 | 67.04 ± 3.55 | 16.72 ± 2.16 | 4.26 ± 0.38 |
| | Sakhir | 7.72 ± 0.02 | 0.53 ± 0.06 | 70.27 ± 2.13 | 12.26 ± 0.09 | 5.06 ± 0.35 |
| Muharraq | Muharraq | 7.61 ± 0.11 | 0.95 ± 0.11 | 64.44 ± 1.39 | 18.55 ± 0.53 | 4.00 ± 0.21 |
| | Hidd | 7.62 ± 0.04 | 1.13 ± 0.17 | 66.85 ± 2.49 | 16.86 ± 0.46 | 0.31 ± 0.05 |
| | Mean | 7.41 ± 0.41 | 1.83 ± 1.08 | 64.96 ± 5.35 | 15.67 ± 3.93 | 3.76 ± 1.39 |
| | Range | (6.61 – 7.77) | (0.53 – 3.37) | (55.09 – 70.27) | (10.13 – 24.17) | (0.31 – 5.06) |

The pH values for of filtered water ranged from 6.61 to 7.23. Filtered water samples from Riffa had the highest concentrations of magnesium (1.52 ± 0.19 mg/L) and sodium (11.24 ± 0.10 mg/L), whereas those from Manama had the highest calcium concentration (39.17 ± 1.16 mg/L).Highest potassium concentration (4.74 ± 0.17 mg/L) in filtered water samples was from Muharraq (Table 3).


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**Table 3: pH and mineral compositions of filtered water in Bahrain (Mean ± SD, n = 5).**

| Governorates | Cities | pH | Magnesium (mg/L) | Calcium (mg/L) | Sodium (mg/L) | Potassium (mg/L) |
|---|---|---|---|---|---|---|
| Capital | Manama | 7.15 ± 0.05 | 0.44 ± 0.05 | 39.17 ± 1.16 | 10.11 ± 0.75 | 0.26 ± 0.05 |
| | Sitra | 7.08 ± 0.27 | 0.35 ± 0.06 | 26.96 ± 2.41 | 11.00 ± 2.16 | 1.94 ± 0.39 |
| Northern | Aali | 6.65 ± 0.12 | 0.10 ± 0.03 | 24.22 ± 2.52 | 10.58 ± 0.12 | 0.21 ± 0.01 |
| | Budaiya | 6.82 ± 0.15 | 0.29 ± 0.06 | 33.62 ± 1.54 | 9.34 ± 0.12 | 0.78 ± 0.01 |
| | Hamad Town | 7.08 ± 0.06 | 1.41 ± 0.26 | 23.01 ± 0.35 | 9.25 ± 0.11 | 4.62 ± 0.08 |
| Southern | Isa Town | 6.98 ± 0.23 | 1.22 ± 0.16 | 36.00 ± 2.89 | 9.97 ± 0.10 | 0.31 ± 0.01 |
| | Riffa | 6.61 ± 0.12 | 1.52 ± 0.19 | 26.75 ± 3.84 | 11.24 ± 0.10 | 1.45 ± 0.16 |
| | Sakhir | 6.87 ± 0.06 | 0.24 ± 0.03 | 37.06 ± 3.91 | 9.30 ± 0.66 | 1.38 ± 0.02 |
| Muharraq | Muharraq | 7.23 ± 0.21 | 0.84 ± 0.03 | 23.78 ± 1.96 | 4.02 ± 0.20 | 4.74 ± 0.17 |
| | Hidd | 7.08 ± 0.07 | 0.30 ± 0.06 | 25.27 ± 1.79 | 5.38 ± 0.56 | 0.28 ± 0.00 |
| | Mean | 6.96 ± 0.24 | 0.67 ± 0.52 | 29.58 ± 6.31 | 9.02 ± 2.41 | 1.59 ± 1.67 |
| | Range | (6.61 – 7.23) | (0.10 – 1.52) | (23.01 – 39.17) | (4.02 – 11.24) | (0.21 – 4.74) |

The pH values for all collected samples of bottled water from the twenty different brands ranged from 7.28 to 8.39. Most of the values reported in the present study coincided with the nutritional information provided by the brands. However,bottled water samples from a brand (BW7) had much lower concentration of magnesium (0.26 ± 0.03 mg/L)than claimed (3.30 mg/L). Another brand (BW9) had much higher potassium concentration (5.04 ± 0.13 mg/L) than claimed (0.40 mg/L) (Table 4).

**Table4: pH and mineral compositions of twenty brands of bottled water in Bahrain.**

| Bottled Water | pH | Magnesium (mg/L) | Calcium (mg/L) | Sodium (mg/L) | Potassium (mg/L) |
|---|---|---|---|---|---|
| BW1 | 7.20 | 10.00 | 15.00 | <10.00 | <0.10 |
| BW1* | 7.48 ± 0.06 | 8.04 ± 0.01 | 18.03 ± 0.73 | 10.57 ± 1.68 | 0.19 ± 0.03 |
| BW2 | 7.00 | 16.00 | <1.00 | 3.00 | 9.00 |
| BW2* | 7.60 ± 0.09 | 16.49 ± 0.49 | 0.25 ± 0.03 | 2.29 ± 0.09 | 11.15 ± 0.08 |
| BW3 | 7.30 | 13.00 | 8.00 | 8.00 | 2.00 |
| BW3* | 7.92 ± 0.08 | 18.04 ± 1.99 | 10.84 ± 0.28 | 10.09 ± 0.16 | 1.91 ± 0.06 |
| BW4 | 6.70 | 18.00 | <0.10 | 3.50 | <0.10 |
| BW4* | 7.66 ± 0.17 | 13.44 ± 0.71 | 0.44 ± 0.06 | 2.90 ± 1.49 | 0.26 ± 0.06 |
| BW5 | 7.00 | 8.00 | 12.00 | 12.00 | 6.00 |
| BW5* | 7.28 ± 0.04 | 7.93 ± 0.02 | 22.47 ± 1.32 | 15.67 ± 0.57 | 7.50 ± 0.21 |
| BW6 | 7.20 | 26.00 | 80.00 | 6.50 | 1.00 |
| BW6* | 7.65 ± 0.04 | 39.69 ± 0.10 | 72.82 ± 1.41 | 10.47 ± 0.98 | 1.18 ± 0.05 |
| BW7 | 6.78 | 3.30 | 15.80 | 1.10 | 0.36 |
| BW7* | 7.79 ± 0.05 | 0.26 ± 0.03 | 13.55 ± 1.03 | 4.11 ± 0.20 | 0.64 ± 0.05 |
| BW8 | 7.71 | 9.60 | 20.00 | 12.43 | 0.35 |
| BW8* | 7.38 ± 0.04 | 8.12 ± 0.01 | 23.18 ± 1.03 | 15.60 ± 1.27 | 1.84 ± 0.08 |
| BW9 | 6.70 | 18.70 | 4.00 | 3.00 | 0.40 |
| BW9* | 7.35 ± 0.03 | 26.75 ± 0.10 | 8.46 ± 1.33 | 3.50 ± 0.36 | 5.04 ± 0.13 |
| BW10 | 7.00 | 16.00 | <1.00 | 3.00 | 9.00 |
| BW10* | 7.43 ± 0.07 | 23.46 ± 0.09 | 0.32 ± 0.178 | 2.69 ± 0.27 | 9.58 ± 0.29 |
| BW11 | 7.80 | 10.10 | 40.50 | 5.60 | 0.70 |
| BW11* | 8.39 ± 0.03 | 8.38 ± 0.01 | 46.97 ± 1.35 | 6.16 ± 1.64 | 1.00 ± 0.04 |
| BW12 | 6.50-8.50 | 20.00 | <1.00 | <2.00 | <1.00 |
| BW12* | 7.55 ± 0.08 | 28.55 ± 0.50 | 0.45 ± 0.16 | 1.14 ± 0.03 | 1.22 ± 0.03 |
| BW13 | 7.00 | 13.00 | 46.00 | 42.00 | N/A |
| BW13* | 7.57 ± 0.09 | 19.57 ± 0.11 | 46.99 ± 1.93 | 43.81 ± 2.47 | 13.37 ± 0.17 |
| BW14 | 7.20 | 10.00 | 20.00 | 3.50 | 5.00 |
| BW14* | 7.76 ± 0.07 | 8.00 ± 0.18 | 24.32 ± 0.90 | 4.69 ± 0.27 | 5.27 ± 0.11 |
| BW15 | 7.20 | 8.40 | 19.00 | <4.00 | <0.10 |
| BW15* | 7.63 ± 0.05 | 7.69 ± 0.01 | 21.42 ± 1.07 | 6.86 ± 0.42 | 0.85 ± 0.03 |


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| | | | | | |
|---|---|---|---|---|---|
| BW16 | 7.36 | 1.60 | 16.20 | 1.00 | 0.30 |
| BW16* | 7.48 ± 0.04 | 2.29 ± 0.11 | 16.24 ± 2.01 | 2.43 ± 0.11 | 1.73 ± 0.02 |
| BW17 | 7.10 | 4.00 | 9.00 | 15.00 | 0.60 |
| BW17* | 7.70 ± 0.09 | 5.75 ± 0.21 | 10.05 ± 0.53 | 18.01 ± 1.34 | 1.08 ± 0.02 |
| BW18 | 8.20 | 1.24 | 14.90 | 5.50 | 0.00 |
| BW18* | 8.07 ± 0.07 | 4.19 ± 0.11 | 20.07 ± 0.61 | 5.38 ± 0.622 | 0.50 ± 0.02 |
| BW19 | 7.00 | 16.00 | <1.00 | 3.00 | 9.00 |
| BW19* | 7.39 ± 0.06 | 13.36 ± 0.36 | 0.19 ± 0.08 | 3.16 ± 0.35 | 7.92 ± 0.26 |
| BW20 | 6.70 | 17.60 | <1.00 | 2.80 | <1.00 |
| BW20* | 7.45 ± 0.26 | 15.84 ± 0.55 | 0.16 ± 0.03 | 0.96 ± 0.14 | 0.30 ± 0.07 |
| Mean* | 7.63 ± 0.27 | 13.79 ± 9.80 | 17.87 ± 18.68 | 8.53 ± 9.59 | 3.63 ± 4.03 |
| Range* | (7.28 - 8.39) | (0.26 - 39.69) | (0.16 - 72.82) | (0.96 - 43.81) | (0.19 - 13.37) |

The values are expressed as mean ± SD.
Number of replicates per brand: 5.
*: Mineral compositions from the present study.
N/A: Information not available.

A summary of all findings of pH and mineral compositions in three types of drinking water in Bahrain is presented in Table 5. The pH values for all drinking water samples ranged from 6.96 to 7.63; in which filtered water samples had the lowest pH value (6.96 ± 0.24), whereas bottled water samples had the highest pH value (7.63 ± 0.27). It was observed that magnesium concentration of all samples ranged from 0.67 mg/L to 13.79 mg/L; in which filtered water samples had the lowest magnesium concentration (0.67 ± 0.52 mg/L) and bottled water samples had the highest (13.79 ± 9.80 mg/L). Calcium and sodium concentrations for all samples ranged from 17.87 mg/L to 64.95 mg/L and 8.53 mg/L to 15.67 mg/L respectively. It was found that bottled water samples had the lowest calcium (17.87 ± 18.68 mg/L) and sodium (8.53 ± 9.59 mg/L) concentrations, whereas tap water samples had the highest calcium (64.95 ± 5.35 mg/L) and sodium (15.67 ± 3.93 mg/L) concentrations. Potassium concentration for all samples ranged from 1.6 mg/L to 3.76 mg/L and was found to be lowest (1.59 ± 1.67 mg/L) in filtered water samples and highest (3.76 ± 1.39 mg/L) in tap water samples.

**Table5: pH and mineral compositions of the three types of drinking water in Bahrain.**

| Drinking Water Samples | pH | | Magnesium (mg/L) | | Calcium (mg/L) | | Sodium (mg/L) | | Potassium (mg/L) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Tap Water (n=50) | 7.41 ± 0.41 | (6.61-7.77) | 1.83 ± 1.08 | (0.53-3.37) | 64.95 ± 5.35 | (55.09-70.27) | 15.67 ± 3.93 | (10.13-24.17) | 3.76 ± 1.39 | (0.31-5.06) |
| Filtered Water (n=50) | 6.96 ± 0.24 | (6.61-7.23) | 0.67 ± 0.52 | (0.10-1.52) | 29.58 ± 6.31 | (23.01-39.17) | 9.02 ± 2.41 | (4.02-11.24) | 1.59 ± 1.67 | (0.21-4.74) |
| Bottled Water (n=100) | 7.63 ± 0.27 | (7.28-8.39) | 13.79 ± 9.80 | (0.26-39.69) | 17.87 ± 18.68 | (0.16-72.82) | 8.53 ± 9.59 | (0.96-43.81) | 3.63 ± 4.03 | (0.19-13.37) |

The Tukey's Honestly Significant Difference (HSD Post Hoc) test revealed that there were no significant differences between potassium concentration in tap and bottled water samples, magnesium concentration in tap and filtered water samples and sodium concentration in filtered and bottled water samples. The remaining results were confirmed to be significantly different between the groups (<0.001).

## IV. DISCUSSION

The pH and mineral compositions of drinking water is very crucial to establish optimal health since extreme changes in pH and the deficiencies and toxicities of minerals can prove to be fatal to human [16]. The pH values of bottled water were higher than those of tap and filteredwaters. Desalination and filtration processes associated with tap and filtered waters could decrease the levels of pH due to the removalmolecules and ions, which act as a buffer in waters [17]. In the present study, all water samples analyzed had pH values within the recommended range by the Environmental Protection Agency, USA (EPA-USA) and World Health Organization (WHO) (6.5 – 8.5) [18].

Magnesium is responsible for nerve stimulant transmission, muscle contraction, protein construction and DNA replication [19]. Magnesium concentration in bottled water was significantly higher than those of tap and filtered waters. Similar findings were obtained by Saleh et al. [20] which indicated that bottled water had higher magnesium concentration (19.54 mg/L) than tap water in Egypt (14.0 mg/L). Likewise, Azlan et al. [21] reported that bottled water had higher magnesium concentration (1.82 mg/L) than tap water (1.1 mg/L) in Malaysia.

In Bahrain, Musaiger and Khungi [9] indicated that tap water had higher magnesium concentration (44.8 mg/L) than filtered (9 mg/L) and mineral bottled water (15.5 mg/L). However, magnesium concentration has drastically decreased in tap and filtered water in the present study.

The Recommended Daily Intake (RDI) of magnesium from food and beverages is set at 420 mg/day [22]. Based on 3.7 litres of water consumption per day, the percentages of magnesium contributions to the RDI through tap, filtered and bottled water in the present study are 1.63%, 0.59% and 12.14% respectively. Therefore, tap and filtered waters unlike bottled water brands, do not provide the minimum magnesium concentration recommended in drinking water which is 10 mg/L and the optimum range is 20 – 30 mg/L [23]. Most of the analyzed bottled water samples analyzed in the present study had magnesium concentration equal to or more than 10 mg/L, except for six brands, which were extremely low in magnesium content.

Low magnesium intake has been associated with an increased risk of cardiovascular disease [24]. A study conducted by Azoulay et al. [25] indicated that magnesium through water is absorbed approximately 30% faster and better than from food. Hence, supplementation of magnesium through drinking water proves to be very beneficial to the human health. In Bahrain, there is a need to fortify tap water with the needed amount of magnesium.

The element calcium is responsible for building of bones, muscle functions, vascular contraction, nerve transmission, intracellular signalling, hormonal secretion and various more functions [26]. According to the present study, calcium concentration was significantly higher in tap water (64.95 ± 5.35 mg/L) than filtered (29.58 ± 6.31 mg/L) and bottled (17.87 ± 18.68 mg/L) water. Similar trends were recorded in Malaysia in which tap water had higher calcium concentration (6.65 mg/L) than bottled water (0.36 mg/L) [21].Conversely,Saleh et al. [20] indicated that bottled water had higher calcium concentration (59.38 mg/L) than tap water (33.9 mg/L) in Egypt.

The addition of hard water (remineralization) at the end of desalination process can contribute to the high calcium concentration in tap water [27]. Calcium concentration in filtered water was significantly lower than tap water due to further purification, which can reduce the concentration of calcium [28].

Musaiger and Khungi [9] indicated that tap water had higher calcium concentration(139.5 mg/L) than filtered (29.5 mg/L) and mineral bottled water (30.2 mg/L) in Bahrain. Calcium concentration of filtered water in the present study was approximately similar to the values reported by Musaiger and Khungi [9]. However, the present study recorded a significant decrease in calcium concentration in tap water, when compared to the mentioned study in 1990. This could be attributed to advancement of desalination processes [29].

The RDI of calcium from food and beverages is set to be 1,300 mg/day [30]. Based on 3.7 litres of water consumption per day, the percentages of calcium contributions to the RDI through tap, filtered and bottled water in the present study are 18.48%, 8.42% and 5.08%, respectively. Studies recommend that calcium concentration in drinking water should be a minimum of 20 mg/L and the optimum range is recommended to be 40 – 80 mg/L[23]. In the present study, calcium concentration in tap and filtered water was higher than 20 mg/L and ranged from 55.09 mg/L to 70.27 mg/L and 23.01 mg/L to 39.17 mg/L respectively, whereas majority of bottled water brands had calcium concentration much lower than 20 mg/L.

The element sodium is responsible for maintaining osmolarity, homeostasis and physiological function of the human body [31]. Sodium concentration was significantly higher in tap water (15.67 ± 3.93 mg/L) than filtered (9.02 ± 2.41 mg/L) and bottled (8.53 ± 9.59 mg/L) water.The average salinity in the Arabian Gulf is around 42 PSU [32]. This could be reflected on the level of sodium in tap water after desalination. Filtered water comprises of significantly lower sodium concentration than tap water in the present study due to further purification [28]. According to Musaiger and Khungi [9]in Bahrain, tap water had higher sodium concentration (309.4 mg/L) than filtered (110.9 mg/L) and mineral bottled water (17.4 mg/L). However, sodium concentration in tap and filtered water has decreased drastically in the present study.

The RDI of sodium is set at 2,300 mg/day for adults [22] and based on 3.7 litres of water consumption per day, the percentages of sodium contributions to the RDI through tap, filtered and bottled water in the present study are 2.52%, 1.45% and 1.37%, respectively.

According to EPA the sodium concentration in drinking water should range from 30 mg/L to 60 mg/L. For hypertension patients, sodium concentration in drinking water is recommended to be 20 mg/L [33]. In the present study, except for bottled water from the brand (BW13), all of the collected samples had sodium concentration below 30 mg/L. No significant difference was observed between sodium concentration of filtered and bottled water.Tap water, according to the present study provides with optimum sodium concentration, whereas sodium levels in filtered water and few of the brands of bottled water are too low and have the potential to cause hyponatremia if drank excessively, especially to those who are more susceptible to the condition such as those who are following low sodium diets [34].

Potassium is an important element responsible for cardiac, skeletal and smooth muscle contraction and is easily absorbed by the gastrointestinal wall when provided via drinking water [35]. Potassium concentration was significantly higher in tap water (3.76 ± 1.39 mg/L) than filtered water (1.6 ± 1.67 mg/L).

According to the previous study conducted by Musaiger and Khungi [9] in Bahrain, mineral bottled water (2.2 mg/L) had the highest potassium concentration, when compared to tap and filtered water which had nil concentration. Potassium concentration in

tap and filtered water analysed in the present study has increased substantially.Filtered water had significantly lower potassium concentration than tap water due to process ofpurification [28].

The RDI recommended for potassium by Food and Drug Administration (US) is 4,700 mg/day [22] and based on 3.7 liters of water consumption per day, the percentages of potassium contributions to the RDI through tap, filtered and bottled water in the present study are 0.29%, 0.12% and 0.28%, respectively. Therefore, it is important not to depend purely on drinking water as a source of potassium.

## V. CONCLUSION

The present study provides an important baseline for further monitoring the quality of water in Bahrain. The study revealed that bottled water had significantly higher pH value and magnesium concentration than tap and filtered water, whereas tap water had significantly higher concentrations of calcium, sodium and potassium than filtered and bottled water. The quality of tap water in Bahrain has improved in comparison with the early 1990s. With an improvement inthe concentration ofmagnesium, tap water could be considered as a better option for dirking water in Bahrain.

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